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ABSTRACT

Minorities have for some time faced underrepresentation in the technical professions. However, recent statistics indicate that many more minorities are enrolled in higher education than ever before. This report centers on identifying the particular difficulties that bilingual Hispanic students majoring in technical subjects have in performing mathematics and physics-related tasks. Further, the research aims at separating the difficulties into those deriving from language deficiencies and those from conceptual ones. The findings cited investigate the relationship between grade point average, language proficiency, and performance on various mathematical tasks for a group of 60 Hispanic bilingual undergraduates majoring in technical subjects. The results indicate that language proficiency is strongly correlated with mathematics performance as well as grade point. This suggests that courses that attempt to raise the level of language proficiency of those Hispanics possessing low skills may improve pupil performance in mathematics or decouple somewhat the interdependence between language proficiency and mathematics performance. (MP)

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The Interdependence of Mathematical Skills, Grade Point Average, and Language Proficiency for Hispanic College Students*†

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Abstract

This presentation will consist of research findings which investigate the relationship between grade point average, language proficiency, and performance on various mathematical tasks for a group of 60 Hispanic bilingual undergraduates majoring in technical subjects. Implications of the findings with respect to the design of curricula to facilitate the academic progress of Hispanics will be discussed.

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Introduction

It has been clear for some time that minorities are underrepresented in the technical professions. However, recent statistics show that many more minorities are enrolled in higher education today than ever before. For example, it is evident from Table 1 that the percentages of Blacks and Hispanics enrolled in undergraduate studies nationwide is not very different from the 1978 Census Bureau figures of 11.6% and 5.6% for the percentages of Blacks and Hispanics, respectively, in the population as a whole. Despite this proportionate representation, the actual percentage of minority students who receive baccalaureate degrees in technical fields, as shown in Table 2, is well below the minority enrollment statistics from Table 1. Table I also shows that minorities are underrepresented in graduate and professional (professional here meaning medical, veterinary, and law professions) programs. These figures are indicative of one, or a combination, of three causes: minority students could be shying away from choosing technical fields of study; the attrition rate in technical fields is very high for minority students; the enrollment of minorities has increased dramatically in the two years spanning Tables 1 and 2. It is my impression that the former two reasons are much more likely to be the cause of the underrepresentation of minorities in technical professions than the latter reason.

Our research at the Bilingual Research Project has centered around identifying the particular difficulties that Bilingual Hispanic students majoring in technical subjects have in performing mathematics and physics-related tasks and, insofar as it is possible, separating the difficulties into those deriving from language deficiencies and those deriving from conceptual difficulties. The results I will present deal with how the performance of these Hispanic students, as measured by either their grade point averages (GPA) or by scores on various math exams, depends upon language proficiency. For purposes of comparisons, we also have data on a group of monolingual English-speaking students majoring in technical subjects.

As our results will show, the mathematical preparation that the "typical" bilingual Hispanic in our study has upon entering a technical program is substantially below that of the "typical" monolingual student. This, coupled with the language barrier, does not make a Hispanic student's progress in the demanding technical fields an easy task. There are, however, certain measures that can be taken which I think will improve on the current situation. I will outline these recommendations at the conclusion of this presentation.

Procedure

Subjects

Subjects consisted of two groups, both comprised of students enrolled in technical programs at a major eastern State university. The first group was composed of 60 Hispanic bilinguals, of whom 35 were Freshmen, 12 were Sophomores, 10 were Juniors, and the remaining 3 Seniors. The majority, namely 36, were engineering majors, while the rest were science majors. All but 9 were balanced bilinguals; that is, they demonstrated nearly equivalent performances in Spanish and English versions of language proficiency exams.

The second group, which served as a norm, consisted of 52 monolinguals, of whom 43 were Freshmen, 5 were Sophomores, and 4 were Juniors. There were 38 engineering majors in the monolingual group, with the remainder majoring in the sciences. Both groups volunteered to participate in the study and were paid for their time.

Description of Exams

The six exams administered were designed to measure advanced reading comprehension proficiency, algebraic skills, and word problem solving skills. The language proficiency exams were Test of Reading, Level 5, and Prueba de Lectura, Nivel 5, developed by Guidance Testing Associates in 1962. These tests contain three subsections, covering vocabulary, speed of comprehension, and level of comprehension. These two exams are equivalent versions, one in English and the other in Spanish. The next two exams, Short Algebra Problems in both English and Spanish, were locally designed and contain 20 questions each. These exams consist of short problems in basic algebra that require little semantic processing. The last pair of exams, Long Word Problems - English and Spanish - consist of 15 word problems in algebra that require a considerable amount of semantic processing and subsequent translation from verbal language to mathematical language (equations). These two exams were also locally designed. The Short Algebra Problem exams are aimed at assessing a student's algebraic facility, which is an essential skill for majors in a technical subject. The Long Word Problem exams are intended to assess a student's ability to read a mathematics problem, translate the problem into mathematical terminology, and solve it. Sample questions from the English versions of these two exams are contained in the Appendix. The Spanish versions of all exams were given only to the bilingual group, while the English versions were administered to both groups. The language proficiency exams were scored on total number correct; in the math exams two points were given for problems totally correct, while one point was given for problems in which a silly error was committed, or for problems in which the students demonstrated the correct procedural approach but obtained an incorrect answer.

Results

Means and standard deviations for all exams, as well as each group's grade point average and SAT score average,* are reported in Table 3. Table 3 also contains the mean GPA for the entire student population and for the engineering student population. It is evident from Table 3 that the monolingual group has a decided advantage over the bilingual group in English language proficiency which may be one of the main causes of the large disparity in the means of the two groups in the other academic performance measures. It can also be seen that the bilingual group does not perform better in their first language, Spanish, on either the language proficiency or on the math exams. The slightly higher means in Spanish in the two math exams is probably due to the fact that the English versions of the exams were always given first; thus by the time the students took the Spanish versions, they knew what to expect and moved slightly faster, thereby finishing more problems in the allotted time.

Table 4 contains the Pearson Correlation Coefficients between the scores on all exams, along with SAT scores and GPAs. The three entries correspond to bilinguals in Spanish, bilinguals in English, and monolinguals, respectively. The first thing that is clear from Table 4 is that the GPA of the Hispanic group is much more strongly correlated to the language proficiency exam scores than is the GPA of the monolingual group. The correlations between GPA, and the two math proficiency exams as well as the SAT-math, are similar for the two groups.

*It should be pointed out that SAT scores were available for only 26 out of the 60 bilinguals, and 43 out of the 52 monolinguals who participated in the study. Because of the small sample size, results concerning SAT scores should be used only for purposes of observing trends.

A surprising result is that the Short Algebra Problems scores are significantly correlated with all language proficiency measures for the bilingual group in both languages. In contrast, the monolingual group shows no statistically significant correlation between language proficiency and the scores on the Short Algebra Problems exam. This is surprising, since one would expect that the ability to solve algebraic problems requiring little semantic processing should not depend upon language proficiency; apparently, this is not the case for the Hispanic group. Finally, Table 4 shows that, even though scores on the Long Word Problem exam are statistically significantly correlated in three out of the four language proficiency measures for the monolingual group, the correlations for the bilingual group are statistically significant with all four language proficiency measures, and across both languages.

Discussion and Conclusions

I would now like to summarize the two important results from this study, and offer possible interpretations for the differences found between the bilingual and the monolingual groups. I will conclude by making several suggestions which hopefully will serve to improve Hispanics' progress in technical fields.

The first obvious difference between the two groups is that *bilinguals are at a lower level of proficiency at solving basic algebra problems that require little semantic processing, as well as at a lower level of language proficiency than monolinguals.* I can offer two reasons contributing to the cause of this difference. A survey given to all students at the end of the testing sessions attempting to study sociological factors showed that there were significant differences in socio-economic status (SES) between the two groups, with bilinguals being at a lower SES level than monolinguals.[1] These differences in SES can indirectly influence the students' academic preparation. For example, bilinguals are more likely than monolinguals to live in low-income neighborhoods, and to attend sub-standard schools where the quality of education received is somewhat below that of a middle-class suburban school. Another possible explanation for this difference is that bilingual Hispanic students may receive less encouragement to pursue technical careers from key influences such as guidance counselors and high school teachers. The survey mentioned above revealed a significant difference in the students' own reasons given as primary motivations for pursuing such a career, in that the majority of the Hispanic students chose "interest only" for this motivation, while the majority of their monolingual counterparts marked the "interest and encouragement" category. This finding was supported by the large percentage (74%) of the monolingual students who indicated that they had received career counseling in this direction during high school, while 64% of the Hispanic students did not ever receive such counseling. Thus, these students decide to pursue a field of study of which they know little in terms of the kind of preparation that is necessary for success, and with little time left in their high school careers to make up any academic deficiencies.

The second result is that *the performance of bilinguals at math tasks, whether or not these tasks require semantic processing, or their performance as measured by their college* GPA, *is very dependent upon language proficiency.* This result could be indicative of a linguistic threshold effect similar to that hypothesized by Cummins.[2] Cummins' hypothesis states that there may be a threshold level of linguistic competence that bilingual children must reach in order to avoid cognitive deficits. The fact that the bilinguals in this study are at a lower language proficiency level (in both languages) than the monolinguals, combined with the fact that the correlation coefficients among the language proficiency measures are significantly stronger for the bilingual group, indicates that language skills, such as level of vocabulary and level of comprehension, may not be utilized independently of each other for the bilingual group. Thus the ability of a bilingual to perform cognitive tasks can be adversely affected if the student has not crossed some critical linguistic threshold. This would explain the stronger correlation between language proficiency and performance on the Long Word Problem exam, or GPA for the bilingual group.

What this hypothesis does not explain are the significant correlations between the language proficiency measures and performance on the Short Algebra Problem exam for the bilingual group, since the Short Algebra Problem exam requires almost no language processing. If mathematics is considered to be another language with its own vocabulary and logical structures, then perhaps the fact that a bilingual has not fully developed his/her proficiency skills in either semantic language can affect the development of proficiency skills in the third language-- mathematics. This would explain the interdependence between language proficiency and performance on the Short Algebra Problem exam. It is plausible that in order for language and mathematics skills to be independent of each other, one language, whether it be English, Spanish, or mathematics, must be developed past some threshold level.

Although there have been numerous investigations which have tudied the relationship between high school class rank, high school GPA, and SAT scores,[3-9] as well as investigations studying how the performance in mathematics courses in college correlate with SAT and other cognitive measures,[10-11] I have found no studies which have investigated the effect of language proficiency upon mathematics performance for bilingual students at the college level. One study by Ayers and Peters[12] did show that GPA and scores on the TOEFL language proficiency exam were significantly correlated for Asians enrolled in graduate technical studies in U.S. universities. Another study by Duran[13] showed that the performance of Puerto Rican bilingual college students at logical reasoning tasks was correlated to language proficiency. It would be interesting to expand our study to include other college-age minority and non-minority students who are at a level of language proficiency similar to the bilinguals in our study, to see if the strong correlation between language proficiency and mathematics performance is a phenomenon of bilingualism, or merely caused by poor language proficiency.

The question now is what university educators can do to improve the retention and progress of Hispanics enrolled in technical fields. Although there is no panacea, I think the few suggestions I will make should prove helpful to most underprepared students pursuing technical fields.

First, it is imperative that an underprepared student be made aware of his/her academic deficiencies before starting in any college program. Often, academically underprepared students are mainstreamed too early. This usually results in more difficulties for the student, who now must not only learn the material in the regular courses, but also make up any deficits as well. If students in this predicament are counseled to resign themselves to spending 5 years in college, the first year being aimed at preparing them academically so they can compete favorably with "regular" students starting the second year, then fewer misunderstandings will occur.

Another suggestion which should help minority students is to interest those who are capable of pursuing a technical profession as early as possible. Since minorities are underrepresented in the technical professions, pre-college minority students have very few role models to emulate. If a concentrated effort is made by university recruiters to reach minority students at the Junior High school level, for purposes of interesting them in a college technical program, as well as to inform them of the kind of effort and preparation it takes to succeed, then the students will be more motivated and have enough time to develop a sound mathematical foundation.

Finally, it is clear that the bilingual group has a decided disadvantage in language proficiency in both English and Spanish. The fact that language proficiency is strongly correlated with mathematics performance as well as college GPA indicates that the role of language in solving problems in a largely symbolic subject like mathematics is more important than could have been anticipated. Thus, any courses which attempt to raise the level of language proficiency of those Hispanics possessing below-average language skills may improve math performance -- or at least decouple somewhat the interdependence between language proficiency and mathematics performance.

Appendix

Sample Questions from the English Version of the Short Algebra Problem, and Long Word Problem, Exams.

Short Algebra Problem Exam:

- Solve for x and y: $\begin{aligned} 2x + y &= 2 \\ x - 3y &= -27 \end{aligned}$

- Factor the following: $4x^2 + 10x - 6$

Long Word Problem Exam:

- In an engineering conference, 9 meeting rooms each had 28 participants, and there were 7 participants standing in the halls drinking coffee. How many participants were at the conference?

- John puts $.15 into his money box every day while his brother Bill secretly takes out $.06 every day. How much money is actually in the money box if John thinks there is $2.25 in it?

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Table 1

Minority Enrollment in Higher Education for 1978
Figures are in percent

	Blacks	Hispanics
undergraduates	10.0	5.3
graduates	5.7	2.3
professional	4.4	2.7

Data from "Fall Enrollment in Higher Education, 1978", A.J. Pepin, National Center for Education Statistics, Washington, DC 1979.

Table 2

Bachelor's Degrees Awarded in Scientific Disciplines
during 1976-1977
Figures are in percent

Field of Study	Blacks	Hispanics	Total Minority
Biological Sciences	4.5	2.9	10.1
Computer Science	5.7	1.8	10.2
Engineering	2.8	2.6	8.1
Health Related	5.4	2.3	9.8
Mathematics	5.0	2.2	9.6
Physical Sciences	3.0	2.0	6.9

Taken from "Data on Earned Degrees Conferred by Institutions of Higher Education by Race, Ethnicity, and Sex, Academic Year 1976-1977". U.S. Dep. of Health, Education and Welfare, Office of Civil Rights, Aug. 1979.

The 1978 Census Bureau statistics show that Blacks and Hispanics comprise 11.6 and 5.6 of the country's population, respectively.

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Table 3

Means and Standard Deviations

Exam	Max. Score	BILINGUALS N = 60 Spanish Mean	Spanish Sta. Dev.	English Mean	English Sta. Dev.	MONOLINGUALS N = 52 English Mean	English Sta. Dev.
Grade Point Average *	4.0	--	--	2.33	.77	2.74	.70
Vocabulary	45	29.0	9.0	29.8	7.5	36.0	4.2
Speed of Comprehension	30	11.5	4.8	10.9	4.5	18.0	4.4
Level of Comprehension	50	23.0	7.9	24.8	8.0	35.0	6.4
Short Algebra Problems	40	22.4	8.8	19.3	9.3	32.1	5.9
Long Word Problems	30	10.7	5.6	9.3	4.5	17.1	4.5
SAT V	800	--	--	327 (n = 26)	96	490 (n = 43)	69
SAT M	800	--	--	435 (n = 26)	128	612 (n = 43)	70

*The GPA of the total student population and the engineering student population are 2.63 and 2.59, respectively.

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Table 4

Pearson Correlation Coefficients Among Variables

Variables	1	2	3	4	5	6	7	8
GPA	1							
Vocabulary	48*** 48*** 30*	1						
Speed of Comprehension	23* 30* 09	70*** 60*** 42***	1					
Level of Comprehension	40*** 36** 05	71*** 66*** 44***	71*** 74*** 41**	1				
Short Algebra Problems	43*** 32** 35**	41*** 40*** -06	30** 46*** 13	45*** 34** 14	1			
Long Word Problems	44*** 49*** 35**	37** 53*** 25*	29* 36** 31*	47*** 41*** 13	54*** 63*** 47***	1		
SAT V [b]	-- 12 23	-- 52** 63***	-- 64*** 59***	-- 63*** 56***	-- 49** 07	-- 47** 15	1	
SAT M [b]	-- 42* 59***	-- 55** 46***	-- 54** 31*	-- 51** 24	-- 85*** 55***	-- 87*** 66***	-- 59*** 41**	1

The first three entries correspond to bilinguals in Spanish, bilinguals in English, and monolinguals in English, respectively.
Decimal points have been omitted; *p<.05 level, **p<.01 level, ***p<.001 level
a) N=52 for monolinguals; b) N=62 for monolinguals and N=26 for bilinguals

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